GEOLOGIC MAP OF THE OPHIR QUADRANGLE, TOOELE COUNTY, UTAH

by Stefan M. Kirby

MAP 257DM
UTAH GEOLOGICAL SURVEY
a division of
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2012

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SCALE: 1:24,000

Cover photo: *View to the southwest across Paleozoic bedrock exposed in the Oquirrh Mountains to unconsolidated deposits in Rush Valley that cover much of the quadrangle. The prominent drainage that flows to the southwest is Ophir Creek.*

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INTRODUCTION

Location and Geographic Setting

The Ophir quadrangle is located in the eastern Basin and Range physiographic province, which is characterized by a series of steep, north-south-trending mountain ranges separated by broad basins. The quadrangle includes part of the southwestern Oquirrh Mountains and adjoining parts of Rush Valley in southeastern Tooele County, 35 miles (56 km) southwest of Salt Lake City and 10 miles (16 km) south of Tooele, Utah. Ophir Creek drains part of the Oquirrh Mountains and flows to the southwest across the quadrangle. The historic mining community of Ophir lies along Ophir Creek in the northeast corner of the quadrangle. The quadrangle contains the Ophir mining district, which is centered on Ophir Canyon and produced a mix of lead-silver-gold, lead-zinc-silver, and copper-lead-zinc ores between the 1860s and the 1970s (Perry and McCarthy, 1977; Rubright, 1978; Krahulec, 1999). Ore deposits consist primarily of skarns, replacement deposits, and fissure deposits localized along major faults and fault intersections (Gilluly, 1932; Rubright, 1978). Other mining occurred parallel to the southwest flank of the Oquirrh Mountains. Ore of lead-silver-gold affinity was mined from host rock in the immediate footwall of the Mercur fault zone and from localized fissure replacements near Mercur Canyon in the West Mercur mining district (Gilluly, 1932; Mako, 1999). Significant gold and mercury production occurred in Mercur Canyon in the adjacent Mercur quadrangle (Mako, 1999). The grounds of the U.S. Army's Tooele Army Depot South Area cover much of the southwest quarter of the quadrangle. The Tooele Army Depot South Area began operation in 1943 as a storage, renovation, and disposal site for chemical weapons and stored much of the nation's stockpile of these weapons until the 1970s. Incineration and final disposal of these weapons began in the 1990s and all remaining chemical munitions were properly disposed of or relocated by early 2012.

Scope of Work

Geologic mapping of the Ophir quadrangle continues a block of geologic mapping in the adjacent parts of Rush Valley including the Vernon, Vernon NE, Lofgreen, Faust, and Saint John quadrangles (see Kirby, 2010a, 2010b, 2010c, 2010d, and 2010e), and was completed in conjunction with a larger mapping project for the Rush Valley 30' x 60' quadrangle (Clark and others, 2009, 2010, and 2012) and a hydrogeologic framework study of the Rush Valley area (Gardner and Kirby, 2011). Geology was mapped directly on digital orthophotographs available from the Utah Automated Geographic Reference Center using ArcGIS, and then transferred to the 1993, 1:24,000-scale, Ophir topographic map base. Available 1:20,000-scale black-and-white aerial photographs (1966) and 5-meter digital elevation data (2005) were also used to delineate geology. Unit description and digital mapping was conducted during several weeks of fieldwork completed during the fall of 2010 and spring of 2011.

Previous Investigations and Mapping Background

Several investigators have mapped the geology of parts of the Ophir quadrangle and adjoining areas at various scales smaller (less detailed) than 1:24,000, including Gilluly (1932), Bucknam (1977), Moore and Sorensen (1979), Everitt and Kaliser (1980), and Tooker and Roberts (1998). Tooker (1987) mapped the Ophir quadrangle at 1:24,000 scale with a focus on the bedrock geology of the Oquirrh Mountains. Several adjoining quadrangles to the south and west have recently been mapped at 1:24,000 scale (Kirby, 2010a, 2010b, 2010c, 2010d, 2010e) and areas surrounding the quadrangle have recently been mapped at 1:62,500 scale (Clark and others, 2012). Everitt and Kaliser (1980), Barnhard and Dodge (1988), Wu and Bruhn (1994), Handwenger and others (1999), and URS Greiner Woodward Clyde (1999, 2001) investigated the paleoseismology of the quadrangle and adjacent areas in Rush Valley. Hydrogeology of the Rush Valley area, including the Ophir quadrangle, is discussed by Hood and others (1969) and Gardner and Kirby (2011).

Geologic Summary

Bedrock in the Ophir quadrangle includes Pennsylvanian- to Cambrian-age sedimentary rocks exposed in the Oquirrh Mountains. These sedimentary rocks consist primarily of marine carbonates with subordinate sections of shale, sandstone, and quartzite that are broadly folded across the north-northwest trending Ophir anticline. A unique section of Middle Cambrian rocks including the Ophir Formation, Bowman Limestone, Hartmann Limestone, and Lynch Dolomite (map units Ꞓop, Ꞓb, Ꞓh and Ꞓly) is exposed near the core of the Ophir anticline consisting of sequences of marine dolomite, limestone, and shale that overlie the Tintic Quartzite (Ꞓt) (plate 2). These rocks are separated from the overlying Pennsylvanian to Devonian rocks by a major Late Devonian disconformity. Immediately overlying the disconformity is the Fitchville Formation and Pinyon Peak Limestone, undivided (map unit MDfp), a stratigraphically complex unit consisting of marine dolomite, limestone, and sandstone. Overlying unit MDfp, a familiar regional sequence of Pennsylvanian to Early Mississippian limestone, shale, and sandstone was deposited. These rock units in ascending order include the Gardison Limestone, Deseret Limestone, Humbug Formation, the members of the Great Blue Limestone, and the Manning Canyon Shale (map units Mg, Md, Mh, Mgbl, Mgblt, Mgbu, and PMmc). Igneous rocks in the quadrangle include a group of related dikes of the Rhyolite of Ophir Canyon (map unit Tro), a pod of the Eagle Hill Rhyolite (map unit Tre), and at least two mafic dikes of the Lamprophyre of Lion Hill (map unit Tll) that cut across sedimentary bedding and some faults at high angles. Similar igneous rocks are exposed in adjoining parts of the Mercur and Stockton quadrangles (Gilluly, 1932; Tooker, 1987; Tooker and Roberts, 1998; Clark and others, 2012).

The major geologic structures in the Ophir quadrangle include the north-northwest-trending Ophir anticline and numerous smaller parasitic folds mapped south of Ophir Creek along the southwest limb of the Ophir anticline. Bedrock is also cut by a series of normal faults that bound the margin of, and offset bedrock within, the Oquirrh Mountains. Named faults mapped within the bedrock of the Oquirrh Mountains include the Lion Hill, Canyon, and Cliff faults. These normal faults dip steeply to the south-southeast, strike to the east-northeast or northeast, and offset bedrock across the axis of the Ophir anticline. A thrust fault, concealed beneath the basin margin and parallel to the Oquirrh Mountains, is inferred based on regional-scale bedrock relations. This structure is assumed to correlate with the steeply dipping Soldier Canyon fault exposed in bedrock to the north in the Stockton quadrangle (Clark and others, 2012).

A series of down-to-the-southwest normal faults cut unconsolidated deposits and bedrock parallel to the margin of the Oquirrh Mountains and define the Southern Oquirrh Mountain fault zone (Everitt and Kaliser, 1980; Barnhard and Dodge, 1988; URS Greiner Woodward Clyde, 1999). The Southern Oquirrh Mountain fault zone in the Ophir quadrangle consists of the Mercur fault zone, Eagle Hill fault, and Lakes of Killarney fault (Wu and Bruhn, 1994; URS Greiner Woodward Clyde, 1999; Clark and others, 2012). These faults dip to the west-southwest and form arcuate and discontinuous systems of fault scarps that extend across the quadrangle. The Mercur fault zone cuts Quaternary deposits, including QTaf, Qafo, Qaf_3, Qaf_2, and deposits as young as Qafy. Based on these map relations, the most recent surface rupture along the Mercur fault zone occurred during the Holocene. Trench studies along strands of the Mercur fault zone north of the Mercur Canyon drainage indicate at least one Holocene rupture with most recent faulting occurring at 4600 ± 200 cal yr B.P. (URS Greiner Woodward Clyde, 2001). Trenches across strands of the Mercur fault zone just south and east of the quadrangle lack numerical age control, but have been interpreted as showing the most recent surface rupture occurred during the early Holocene (Everitt and Kaliser, 1980) or late Pleistocene (Barnhard and Dodge, 1988). Scarp height along the Mercur fault zone ranges from 3 to 21 feet (1–7 m). The Lakes of Killarney fault is mapped along the margin of the Oquirrh Mountains near the mouth of Ophir Canyon where it offsets Mississippian bedrock and QTaf unconsolidated deposits, but does not appear to cut Qafo and younger unconsolidated map units in the Ophir quadrangle (URS Greiner Woodward Clyde, 1999). In contrast, cosmogenic ^{14}C ages for a bedrock scarp of the Lakes of Killarney fault north of the Ophir quadrangle indicate Holocene timing (4360 ± 1220 cal yr B.P.) for the most recent rupture (Handwerger and others, 1999). This discrepancy may suggest that at least part of the Lakes of Killarney fault slips in conjunction with the Mercur fault zone to the south. Several other unnamed fault scarps are mapped to the west of the Southern Oquirrh Mountain fault zone, including a previously unmapped north-northwest-striking and east-facing scarp up to 25 feet (8 m) high that may be an eastern strand of the Mid Valley horst (alternately termed the Saint John Station fault zone [Barnhard and Dodge, 1988]) described by Everitt and Kaliser (1980) and mapped by Kirby (2010d) in the adjoining Saint John quadrangle. No evidence of post-Bonneville surface rupture is apparent along this scarp. For a complete discussion of paleoseismology of the Southern Oquirrh Mountain fault zone see the consultant reports by URS Greiner Woodward Clyde (1999 and 2001). The subsurface dip and location of the Southern Oquirrh Mountain fault zone is supported by a continuous gravity gradient along this margin of Rush Valley (Everitt and Kaliser, 1980; URS Greiner Woodward Clyde, 1999; Kirby and Hurlow, in preparation).

Quaternary and Tertiary? unconsolidated deposits cover the southwestern two-thirds of the Ophir quadrangle. Unconsolidated deposits are broadly divisible into alluvial and lacustrine deposits that are separated by the highstand shoreline of Lake Bonneville. This shoreline is mapped at approximately 5190 feet (1580 m) in the southern half of the quadrangle and 5220 feet (1590 m) in the northern half of the quadrangle (table 1, on plate 2). The change in highstand shoreline elevation occurs near the Ophir Creek channel on the Tooele Army Depot South Area and may be due to (1) movement across strands of the Southern Oquirrh Mountain fault zone, (2) differential post-Lake Bonneville flexure or isotatic rebound, or (3) local variations in wave and shoreline processes during the highstand of Lake Bonneville. Currey (1982) reported a Bonneville highstand shoreline elevation of 5220 feet (1591 m) for a location in the northwest quarter of the Ophir quadrangle.

Deposits and landforms relating to the shoreline include erosional benches, constructional beach ridges, spits, and barrier bars with correlative lagoon-fill deposits. Below the highstand shoreline of Lake Bonneville, surficial deposits are characterized by a mix of lacustrine, alluvial, and fluvial deposits. Above the shoreline, surficial deposits include west- and southwest-sloping alluvial-fan, fluvial-channel, and terrace deposits that range in age from historical to early Pleistocene or Pliocene(?). Older basin fill, including the Salt Lake Formation(?), underlies unconsolidated basin fill across much of the quadrangle (Everitt and Kaliser, 1980; Gardner and Kirby, 2011). Older basin fill includes a range of unconsolidated to semiconsolidated, generally fine-grained lacustrine and alluvial deposits that are well exposed to the south in the Vernon NE quadrangle (Kirby, 2010a). The total thickness of unconsolidated deposits and basin fill in the Ophir quadrangle, estimated from gravity anomalies and well log data in adjoining quadrangles (Everitt and Kaliser, 1980; Kirby and Hurlow, in preparation), may be greater than 3000 feet (1000 m) beneath parts of the Tooele Army Depot South Area.

The early tectonic history of the quadrangle is recorded by exposed Cambrian-age strata that were deposited across a shallow, slowly subsiding continental shelf typical of the eastern Great Basin during the early Paleozoic (Hintze and Kowallis, 2009). Ordovician, Silurian, and Devonian sedimentary rocks typical of the eastern Great Basin are lacking in the quadrangle and instead, this interval is marked by a prominent disconformity that separates Middle Cambrian and Late Devonian rocks. The disconformity may represent a prolonged period of nondeposition or more likely a Middle to Late Devonian period of localized uplift, associated with the compartmentalization of depositional systems and deformation of the early Paleozoic continental shelf (Rigby, 1959). Following Devonian erosion and/or nondeposition, episodic shelf carbonate deposition continued throughout the Mississippian. During the latest Mississippian and throughout the Pennsylvanian continental shelf deposition was replaced by deposition in the rapidly subsiding Oquirrh basin (Geslin, 1998). These rocks were later broadly folded across the Ophir anticline and a series of smaller parasitic folds during east-directed thrust faulting and compression during the Late Jurassic to Eocene Sevier orogeny (Armstrong, 1968; Tooker and Roberts, 1998; DeCelles and Coogan, 2006, and references therein). During the Eocene, crustal shortening produced by the Sevier orogeny was replaced by roughly east-west extension (relaxation of the thrust belt) and significant regional volcanism (Constenius, 1996; Constenius and others, 2003). Eocene volcanism in the Ophir quadrangle resulted in emplacement of dikes and development of associated ore deposits of the Ophir mining district (Gilluly, 1932; Rubright, 1978; Krahulec, 1999). Post-Eocene extension created large basins separating uplifted mountain ranges reminiscent of the modern topography. Extension remains the dominant tectonic style in the area, but it has varied in magnitude, style, and extent throughout Eocene to Holocene time (Stewart, 1998). Major pulses of extension, during the Miocene and possibly the Pliocene, correlate with deposition and deformation (faulting and folding) of the Salt Lake Formation (Perkins and others, 1998). Subsequent extension has controlled deposition of unconsolidated sediments and surface faulting during the Quaternary (Everitt and Kaliser, 1980).

MAP UNIT DESCRIPTIONS

QUATERNARY

Disturbed Land

Qhm **Mining-related human disturbance** (Historical) – Excavations, fill, and tailings associated with historic mining activity; material includes angular cobble-size clasts, gravel, sand, silt, and clay; variable thickness 0 to 60 feet (0–18 m).

Qh **Human disturbance** (Historical) – Excavations, soil disturbance, and associated fill; mapped at gravel pits, disposal pits, earthen dams, and previously developed parts of the Tooele Army Depot South Area in the west half of the quadrangle; mapped where surficial grading, road building, excavations, and associated fill obscure the underlying unconsolidated deposits; material includes sand, gravel, angular cobble-size clasts, silt, and clay; variable thickness from 0 to 50 feet (0–15 m).

Alluvial Deposits

Qal_1 **Youngest alluvial deposits** (upper Holocene) – Moderately to well-sorted sand, pebble, and cobble gravel, silt, and minor clay; deposited along the Ophir Creek drainage; locally includes small alluvial-fan and colluvial deposits; mapped along incised channels that include the active fluvial channel of Ophir Creek; postdates regression of Lake Bonneville and is incised into alluvial (Qaly) and alluvial-fan deposits (Qafy and Qaf_1); thickness variable, probably less than 10 feet (3 m).

Qaly **Younger alluvial deposits** (Holocene to upper Pleistocene) – Moderately to well-sorted sand, pebble and cobble gravel, silt, and minor clay; deposited along the Ophir Creek drainage; locally includes small alluvial-fan and colluvial deposits; mapped along incised drainages where alluvial deposits cannot be differentiated because of map scale or in areas where the specific age of Holocene deposits cannot be determined; postdates regression of Lake Bonneville; thickness variable, probably less than 15 feet (5 m).

Qat **Stream-terrace deposits, undivided** (Holocene to upper Pleistocene) – Moderately to well-sorted sand, pebble and cobble gravel, silt, and minor clay; deposited as a gently sloping terrace near the mouth of Mercur Creek and West Dip Gulch where only a single terrace level is developed; includes inactive stream and floodplain deposits; terrace deposits lie 10 to 20 feet (3–6 m) above active stream and floodplain levels; several soil pits dug into Qat deposits near West Dip Gulch and Mercur Canyon revealed stage IV soil carbonate development (URS Greiner Woodward Clyde, 1999); thickness variable from 5 to 20 feet (2–6 m).

Qat_1 **Level-1 stream-terrace deposits** (lower Holocene) – Moderately to well-sorted sand, pebble and cobble gravel, silt, and minor clay; deposited as a gently sloping terrace near the mouth of Ophir Creek; lowest level and presumably youngest of a set of four terrace levels along Ophir Creek, terrace is incised into Qat_2, Qat_3, and Qafo; terrace is 5 to 10 feet (2–3 m) above Qaly and the active Ophir Creek channel (Qal_1); this terrace is developed west of the trace of the Mercur fault zone; thickness is between 5 and 10 feet (2–3 m).

Qat_2 **Level-2 stream-terrace deposits** (lower Holocene to upper Pleistocene) – Moderately to well-sorted sand, pebble and cobble gravel, silt, and minor clay; deposited as a gently sloping terrace near the mouth of Ophir Creek; intermediate terrace level that is incised into Qafo; Qat_2 terrace is 10 to 15 feet (3–5 m) above youngest terrace (Qat_1) and 20 to 30 feet (6–9 m) above Qaly along Ophir Creek; this terrace level overlies and is uncut by the trace of the Mercur fault zone; thickness is between 5 and 10 feet (2–3 m).

Qat_3 **Level-3 stream-terrace deposits** (upper Pleistocene) – Moderately to well-sorted sand, pebble, and cobble gravel, silt, and minor clay; deposited as a gently sloping terrace north of Ophir Creek west of the trace of the Mercur fault zone; intermediate terrace level that is incised into Qafo and is above the youngest terrace (Qat_1); this terrace level is mapped west of Qat_1 and does not directly adjoin Qat_2; Qat_3 terrace is divided from Qat_2 on the basis of its higher apparent level, alternatively Qat_2 and Qat_3 may be equivalent in age; thickness is between 5 and 10 feet (2–3 m).

Qat_4 **Level-4 stream-terrace deposits** (upper Pleistocene) – Moderately to well-sorted sand, pebble and cobble gravel, silt, and minor clay; deposited as a terrace north of Ophir Creek east of the trace of the Mercur fault; oldest terrace level that is incised into oldest alluvial-fan deposits (QTaf); this terrace level is developed approximately 100 feet (30 m) above the active (Qal_1) channel of Ophir Creek; the significant height above the active floodplain and the development of this terrace on the QTaf deposits suggest this terrace is Pleistocene in age; thickness is up to 20 feet (6 m).

Qafh **Historical alluvial-fan deposits** (historical) – Light colored, moderately sorted sand, silt, gravel, and clay; clasts subrounded to angular and matrix supported; deposited by debris flows and sheet floods along the Mercur Creek drainage in Rush Valley; most if not all of the material in this deposit is mine tailings and debris from historic mining along the upper part of the Mercur Creek drainage in the adjoining Mercur quadrangle (Mike Ford, BLM, verbal communication, 2011); unit overlies undivided Holocene alluvial-fan deposits (Qafy); total thickness is up to 10 feet (3 m).

Qaf_1 **Level-1 alluvial-fan deposits** (upper Holocene) – Poorly to moderately sorted, crudely stratified or massive, pebble to cobble gravel with boulders (near bedrock exposures), sand, silt, and minor clay; clasts angular to subrounded and commonly matrix supported; deposited principally by debris flows and sheet floods at the mouths of small, intermittent stream channels, and near the mouths of other channels in older alluvial-fan or lacustrine deposits and other unconsolidated deposits; locally incised into and/or overlying older alluvial-fan deposits; deposits equivalent to, and grade into the younger part of young alluvial-fan deposits (Qafy); differentiated from other alluvial-fan deposits based on a relatively smooth undissected fan surface morphology radiating away from a defined fan apex and deposition overlying or incised into other alluvial and lacustrine units; no fault scarps cut Qaf_1 deposits in the quadrangle; mapped along channels and across alluvial-fan surfaces near the Ophir Creek channel and along the West Dip Gulch and Mercur and Dry Canyon drainages; this alluvial-fan unit has stage I to I+ soil carbonate development (URS Greiner Woodward Clyde, 1999); exposed thickness up to 20 feet (6 m).

Qaf_2 **Level-2 alluvial-fan deposits** (lower Holocene) – Poorly to moderately sorted, crudely stratified or massive, pebble to cobble gravel with boulders (near bedrock exposures), sand, silt, and minor clay; clasts angular to subrounded and commonly matrix supported; deposited principally by debris flows and sheet floods; locally incised into and/or overlying older alluvial-fan deposits and lacustrine deposits; equivalent to, and grades into the older part of Qafy, locally above younger Qafy deposits; locally overlain by alluvial-fan level-1 (Qaf_1) deposits; overlies Qaf_3 and is inset into Qafo deposits; no fault scarps offset Qaf_2; mapped along Silverado Canyon and south of West Dip Canyon; although no soil pits were dug within the mapped extent of this unit, correlative alluvial-fan units of URS Greiner Woodward Clyde (1999) have stage II or III soil carbonate development; exposed thickness less than 20 feet (6 m).

Qaf_3 **Level-3 alluvial-fan deposits, Bonneville lake cycle, undivided** (upper Pleistocene) – Poorly to moderately sorted, crudely stratified or massive, sand, pebble gravel, silt, and minor clay; clasts subangular to subrounded and commonly matrix supported; deposited principally by debris flows and sheet floods; locally incised into older alluvial fan deposits; locally above younger Qafy deposits and inset into older Qafo fan deposits; fan surface grades to near and just below the Lake Bonneville highstand shoreline and exposures of Lake Bonneville sediments; deposition was contemporaneous with transgression, highstand, and regression of Lake Bonneville in Rush Valley and no shorelines exist on these alluvial fans; surface is incised by active drainages; scarps 3 to 9 feet (1–3 m) high are present on Qaf_3 deposits along the trace of the Mercur fault zone; two soil pits dug in this unit revealed stage I and IV soil carbonate development (URS Greiner Woodward Clyde, 1999); exposed thickness is up to 20 feet (6 m).

Qafy **Younger alluvial-fan deposits** (Holocene to upper Pleistocene) – Poorly to moderately sorted, crudely stratified or massive, pebble to cobble gravel with boulders (near bedrock exposures), sand, silt, and minor clay; clasts angular to subrounded and commonly matrix supported; deposited principally by debris flows and sheet floods at the mouths of intermittent stream channels draining bedrock, near the mouths of other channels in older alluvial-fan and other unconsolidated deposits, or across large alluvial slopes where individual fan surfaces cannot be differentiated; includes level-1 and -2 alluvial-fan deposits (Qaf_1 and Qaf_2) that postdate Lake Bonneville and the youngest part of alluvial fans deposited during the Lake Bonneville regression (Qaf_3); also mapped in areas where the specific age of deposits that postdate the Lake Bonneville highstand cannot be determined; unit drapes over or is partially cut by the Mercur fault zone west of West Dip Gulch where vertical offset across scarps is 3 feet (1 m), and south of Mercur Creek where vertical offset across scarps is 3 to 6 feet (1–2 m); a single soil pit dug in this unit south of the mouth of Silverado Canyon revealed stage I soil carbonate development (URS Geiner Woodward Clyde, 1999); thickness is variable, and may be greater than 40 feet (12 m).

Qafo **Older alluvial-fan deposits, pre-Bonneville lake cycl**e (upper to lower Pleistocene) – Poorly sorted, pebble to cobble gravel, locally bouldery, in a matrix of sand, silt, and clay; mapped in areas where pre-Bonneville lake cycle alluvial-fan deposits are undifferentiated because they are poorly exposed or lack distinct geomorphic expression; unit is deeply incised within the oldest (QTaf) alluvial fans in the northwest part of the quadrangle; incised by and alternately overlain by post- and syn-Bonneville alluvial-fan units (Qafy, Qaf_1, Qaf_2, and Qaf_3); prominent erosional and depositional shoreline features produced by the transgression and regression of Lake Bonneville are mapped on this unit; vertical offset across scarps of the Mercur fault zone on this unit range in height between 3 and 21 feet (1–7 m), and Qafo overlies and is uncut by the trace of the Lakes of Killarney fault near Silverado Canyon; URS Greiner Woodward Clyde (1999) documented stage III+ to IV soil carbonate development in six soil pits dug in this unit; unit is mapped below the Bonneville highstand shoreline in the northwest corner of the Ophir quadrangle and the adjoining part of the Saint John quadrangle where surface morphology is fan-like and obvious Lake Bonneville sediments are absent; thickness is probably less than 60 feet (18 m).

Mass-Movement Deposits

Qmtc **Talus and colluvium** (Holocene to upper Pleistocene) – Angular cobble and boulder-size talus and associated sand and gravel-size colluvium; mapped in the Oquirrh Mountains where unit obscures bedrock; total thickness less than 40 feet (12 m).

Lacustrine Deposits

Qlgb **Lacustrine gravel and sand deposits, Bonneville lake cycle** (upper Pleistocene) – Moderately to well-sorted, subrounded to rounded pebble gravel, sand, and minor silt; deposited as gravel bars, barriers, swales, and sheets at and below the Lake Bonneville highstand; deposited during the transgressive or regressive phase of Lake Bonneville; these deposits may include deposits related to the Lake Shambip shoreline (near ~ 5050 feet [1539 m] in elevation [Clark and others, 2012]) of Rush Valley in the south part of the quadrangle where the Shambip shoreline is poorly defined; thickness is less than 40 feet (12 m).

Qlsb **Lacustrine sand deposits, transgressive phase of the Bonneville lake cycle** (upper Pleistocene) – Moderately to well-sorted sand, silt, and minor gravel, deposited in sheets below and abutting the Lake Bonneville highstand; mapped along a set of broad, gently sloping shoreline platforms in the west-central part of the quadrangle; deposited during the transgressive and highstand phase of Lake Bonneville; thickness less than 20 feet (6 m).

Qllb **Lacustrine lagoon deposits** (upper Pleistocene) – Light-colored, well-sorted silt, marl, clay, and sand deposited landward of Qlgb gravel bars and barriers along the Lake Bonneville highstand shoreline in geomorphic depressions; deposited during the highstand of Lake Bonneville; locally covered by veneer of alluvial or eolian deposits; thickness less than 20 feet (6 m).

Qlf **Lacustrine fine-grained deposits, transgressive and regressive? phase of the Bonneville lake cycle** (upper Pleistocene) – Light-colored, moderately to well-sorted silt, clay, marl, and sand deposited below the Lake Bonneville highstand; unit is mapped along gently sloping areas of the valley floor, in the southwest part of the quadrangle, where the surface is dominated by a variety of fine-grained lacustrine deposits either too thin or stratigraphically complex to map separately; includes fine-grained sediment deposited during both the transgressive and regressive phases of Lake Bonneville in Rush Valley; thickness less than 30 feet (10 m).

Spring Deposits

Qsm **Spring and marsh deposits** (Holocene) – Moderately to well-sorted silt, sand, clay, and dark organic-rich material deposited in areas of high water tables, perennial spring flow, and seasonal standing water in the Ophir quadrangle; mapped in several broad low-gradient areas and confined channels along the valley floor with seasonal or perennial standing water and/or shallow ground water; unit is inset within or overlies Qlf deposits in the southwest part of the quadrangle; total thickness up to 30 feet (10 m).

Eolian Deposits

Qei **Eolian silt and sand deposits** (Holocene) – Very well sorted silt and fine-grained sand deposits that consist of small vegetated dunes up to 3 feet (1 m) tall, and sheets and small swales of sediment that lack evidence of sheet flooding; mapped in one area in the southeast corner of the quadrangle where the Bonneville highstand shoreline is obscured and surface texture appears to be the result of eolian processes; unit abuts and locally obscures traces of the Mercur fault zone; total thickness up to 15 feet (5 m).

Mixed-Environment Deposits

Qla **Lacustrine and alluvial deposits, undivided** (Holocene to upper Pleistocene) – Poorly to well-sorted sand, gravel, silt, clay, and marl; mapped below and abutting the Lake Bonneville highstand shoreline in the southeast quarter of the quadrangle where alluvial and lacustrine deposits cannot be subdivided and relative age of deposit is ambiguous; unit locally contains small gastropods less than 0.2 inch (5 mm) in diameter; thickness up to 40 feet (12 m).

Qlay **Lacustrine and younger alluvial-fan deposits, undivided** (Holocene to upper Pleistocene) – Poorly to moderately sorted sand, silt, clay, gravel and marl; deposited below the Lake Bonneville highstand as smooth, sloping sheets of sediment; generally lacks well-developed shoreline features; includes a variety of lacustrine and alluvial facies either too complex or too poorly exposed to map separately; unit includes upper Pleistocene lacustrine sediments reworked by Holocene alluvial fans; mapped below highstand of Lake Bonneville; unit is commonly inset within Qafo or Qlao deposits; thickness less than 40 feet (12 m).

Qlao **Lacustrine and older alluvial-fan deposits, undivided** (upper Pleistocene) – Poorly to well-sorted sand, gravel, silt, clay, and marl; mapped below the Lake Bonneville highstand as sloping sheets and swales of sediment; incised by post-Bonneville alluvial channels and fans; includes a variety of lacustrine and alluvial facies either too complex or too poorly exposed to map separately; locally contains small gastropods less than 0.2 inch (5 mm) in diameter; mapped below and abutting the Lake Bonneville highstand shoreline in the southwest quarter of the quadrangle; unit includes upper Pleistocene alluvial-fan deposits (Qafo) reworked during the transgression and regression of Lake Bonneville; thickness less than 60 feet (18 m).

Qac **Alluvial and colluvial deposits, undivided** (Holocene to upper Pleistocene) – Poorly to moderately sorted sand, gravel, silt, and clay; mapped in isolated areas of bedrock-bounded colluvium and alluvium in the Oquirrh Mountains and adjoining foothills south of Ophir Creek; unit separated from Qmtc by a lack of talus; thickness up to 30 feet (10 m).

Stacked-Unit Deposits

Qc/Mgb **Colluvium over the Great Blue Limestone** (Holocene to upper Pleistocene/Upper Mississippian) – Poorly sorted, locally derived colluvium and talus that consists of gravel, sand, silt, and clay; mapped where colluvium obscures bedding and thinly mantles the Great Blue Limestone in the northeast quarter of the quadrangle, between Ophir and Mercur Canyons; cover unit thickness less than 10 feet (3 m).

QUATERNARY-TERTIARY

QTaf **Oldest alluvial-fan deposits** (lower Pleistocene? to Pliocene?) – Poorly sorted boulder, cobble, and pebble gravel, sand, silt, and clay; unit composed of unconsolidated boulders, cobbles, and gravels; clasts include sandstone, limestone, quartzite, and various Paleozoic carbonates sourced from bedrock exposed to the east in the Oquirrh Mountains; QTaf is the highest-level alluvial-fan unit and is deeply incised (with incision greater than 40 feet [13 m] in many places); fault scarps up to 25 feet (8 m) high are present on QTaf along the Mercur fault zone and to the west where QTaf is exposed above the Lake Bonneville highstand shoreline; soil pit data from URS Greiner Woodward Clyde (1999) indicate stage II to IV soil carbonate development in this unit; thickness up to 300 feet (90 m).

QTbf **Basin-fill deposits, undivided** (Holocene to Miocene) – Combined unit that consists of surficial unconsolidated deposits of Holocene to Pleistocene age and underlying older basin fill that likely consists primarily of the Salt Lake Formation, may include basin fill as old as Eocene or Oligocene deposited during early extension; shown only on cross section; total thickness in quadrangle, based on gravity data (Kirby and Hurlow, in preparation), is up to 3000 feet (910 m).

TERTIARY

Tsl? **Salt Lake Formation?** (Miocene) – White to pale-greenish-yellow to grayish-yellow marl, siltstone, and sandy siltstone; marl is lithified, poorly bedded, and commonly contains charophyte fragments up to 0.2 inch (4 mm) in length; silty and sandy parts of the unit are weakly lithified and generally poorly exposed with no observable bedding; unit is approximately flat-lying although no bedding orientations were measured because of poor bedding and poor exposure; unit is exposed at several outcrops within the Tooele Army Depot South Area grounds, in the west-central part of the quadrangle, that are partially mantled by Qlgb or Qlao; similar outcrops of Tsl are mapped in the adjoining Saint John quadrangle to the west (Kirby, 2010d); Miocene age (roughly 6 to 9 Ma) of the deposits is taken from ash correlation ages presented by Perkins and others (1998) for the Salt Lake Formation in the adjoining Vernon NE and Faust quadrangles; exposed thickness is less than 20 feet (6 m); total thickness based on boreholes in the adjoining Vernon NE quadrangle is up to 3600 to 4200 feet (1100–1280 m) (Kirby, 2010a); map unit designation is queried due to poor exposures.

Tre **Eagle Hill Rhyolite** (Late Eocene) – White to yellowish-gray to moderate-orange-pink rhyolite and rhyolite porphyry; commonly aphanitic with phenocrysts of quartz and biotite; unit is locally flow banded; mapped at a single outcrop just south of Mercur Canyon where it steeply cuts the Great Blue Limestone and the Humbug Formation; more significant exposures are mapped in the adjoining Mercur quadrangle (Laes and others, 1997; Clark and others, 2012); $^{40}Ar/^{39}Ar$ age of 32.34 ± 0.19 Ma (Utah Geological Survey and Nevada Isotope Geochronology Laboratory, 2012), previous K-Ar age of 31.6 ± 0.9 Ma (Moore, 1973); major-oxide and trace-element geochemistry is similar to the rhyolite of Ophir Canyon (figures 1 and 2, tables 2 and 3, on plate 2), but age difference and spatial discordance warrant separation of the two units; outcrop in the quadrangle is up to 260 feet (80 m) in width.

Tro **Rhyolite of Ophir Canyon** (Late Eocene) – White to pale-yellowish-orange or yellowish-gray rhyolite dikes and pods that cut Paleozoic-age bedrock; generally fine-grained rhyolite with phenocrysts, 0.04–0.08 inch (1–2 mm) in length, of sanidine, quartz, and occasionally biotite; flow banding is apparent in the dike in Ophir Canyon; all dikes appear to be near vertical; exposures include a prominent north-south trending dike on the north wall of Ophir canyon and several smaller, discontinuous, generally north-south trending dikes exposed between Silverado and Mercur Canyons; the rhyolite dike in Ophir Canyon cuts across both the Canyon and Cliff faults with no apparent offset, implying intrusion postdates faulting there; sample 1831 of the rhyolite dike in Ophir Canyon yielded a weighted mean U-Pb zircon age of 36.64 ± 1.40 Ma (tables 4 and 5, on plate 2); unit is separated from the Eagle Hill Rhyolite based on ages that do not overlap and spatial discordance; major-oxide and trace-element geochemistry is similar to the Eagle Hill Ryholite (figures 1 and 2, tables 2 and 3, on plate 2); dike outcrops range in width from less than 1 foot to 30 feet (0.3–10 m) and extend up to 3200 feet (980 m) laterally; the southernmost of these dikes extends into an 80-foot-wide (25 m) pod of rhyolite.

Tll **Lamprophyre of Lion Hill** (Eocene) – Dark-gray to greenish-black lamprophyre dikes; heavily altered and poorly exposed dike near the crest of Lion Hill and north of the town of Ophir just east of Hartmann Gulch; these dikes have been extensively mined and no in-place samples were found during this study; Gilluly (1932) reported hand specimens consisting of altered biotite and olivine replaced by serpentine(?), and in thin section, altered biotite, olivine, augite, and labrodorite were noted; near Ophir the lamprophyre dike terminates against and may be cut by a strand of the Canyon fault, implying an age of emplacement that predates slip along the Canyon fault and therefore also predates emplacement of the Eagle Hill Rhyolite; both dikes dip vertically and have an estimated width of 1 to 4 feet (0.3–1 m).

PERMIAN-PENNSYLVANIAN

PIPo **Oquirrh Group, undivided** (Lower Permian to Lower Pennsylvanian) – Not exposed in the quadrangle and shown only on cross section; limestone, sandstone, and quartzite; lithology is assumed to be similar to Oquirrh Group bedrock mapped in adjoining quadrangles (Tooker and Roberts, 1998; Clark and others, 2012) and exposed nearby in the Oquirrh Mountains; total thickness is greater than 10,000 feet (3000 m).

PENNSYLVANIAN-MISSISSIPPIAN

PMmc **Manning Canyon Shale** (Lower Pennsylvanian to Upper Mississippian) – Generally dark-colored, grayish-black to greenish-black, lithologically diverse unit of interbedded shale, limestone, quartzite, sandstone, and siltstone; in the Ophir quadrangle outcrops of Manning Canyon Shale consist primarily of dark-colored shale and calcareous siltstone with a few interbeds of quartzite and limestone up to 4 feet (1 m) thick; quartzite commonly has a distinctive vitreous pleochroism; all Manning Canyon lithologies tend to be laterally discontinuous, however shale and quartzite beds are more continuous than either limestone or sandstone beds; upper contact with the Oquirrh Group is not exposed in the quadrangle but is regionally conformable (Clark and others, 2012); conformably overlies the Great Blue Limestone south of Ophir Creek in the core of a syncline and across a series of smaller-scale folds; north of Ophir Creek a series of incomplete outcrops are surrounded by map unit QTaf; based on mine workings and mine maps (Gilluly, 1932), the hanging wall of the Mercur fault zone between Ophir and Mercur Creeks consists of Manning Canyon Shale; age is from Webster and others (1984); incomplete thickness between 500 and 600 feet (150–180 m); along the east limb of the Ophir anticline in adjoining quadrangles the Manning Canyon Shale is approximately 1200 feet (400 m) thick (Clark and others, 2012).

MISSISSIPPIAN

Mgb **Great Blue Limestone, undivided** (Upper Mississippian) – Greenish- or medium-bluish-gray to light-bluish-gray, medium- to thick-bedded limestone and fossiliferous limestone; rugose corals, crinoid columns, various brachiopods, and fossil hash are common; mapped north of Ophir Creek where a series of fault-bounded and/or poorly exposed and incomplete outcrops preclude subdivision of the Great Blue Limestone; thickness is between 700 and 2500 feet (210–760 m).

Mgbu **Great Blue Limestone, upper member** (Upper Mississippian) – Greenish- or medium-bluish-gray to light-bluish-gray, medium- and occasionally thin-bedded limestone, fossiliferous limestone, argillaceous limestone, and cherty limestone; forms prominent cliffs and ledges; common fossils include rugose corals 3 inches (10 cm) in length and crinoid stems; dark-brown to grayish black-weathering chert blebs or pods up to 2 inches (5 cm) in diameter occur in some sections; unit is generally thinner bedded than the lower member of the formation (Mgbl) but otherwise the two members are lithologically similar and only subdivided by the intervening Long Trail Shale Member (Mgblt); exposed along the southwest margin of the Oquirrh Mountains between Ophir and Mercur Creeks where it is folded by a series of anticlines and synclines; upper contact is conformable and mapped at the transition to the dark-colored shale of the Manning Canyon Shale north of Silverado Canyon; to the south the upper contact is not exposed and may be truncated by strands of the Mercur fault; lower contact is mapped along the conformable transition to olive-brown to greenish-black shales of Mgblt; age is from Gordon and others (2000); north of Mercur Canyon thickness is between 2500 and 2800 feet (760–850 m); Gilluly (1932) reported a thickness of 3000 feet (915 m) for the upper Great Blue in the southwest Oquirrh Mountains.

Mgblt **Great Blue Limestone, Long Trail Shale Member** (Upper Mississippian) – Moderate-olive-brown to greenish-black carbonaceous and calcareous shale, siltstone, and quartzite; forms slopes and recesses between more-resistant Great Blue Limestone outcrops; exposed as a thin southwest-dipping band along the southwest flank of the Oquirrh Mountains; conformable with the limestone of overlying Mgbu and underlying Mgbl units; unit is thinned by bedding-parallel slip along the Lakes of Killarney normal fault between Ophir Creek and Silverado Canyon; age is from Gordon and others (2000); total thickness is between 55 and 110 feet (17–33 m); Gilluly (1932) reported a thickness of 85 feet (26 m).

Mgbl **Great Blue Limestone, lower member** (Upper Mississippian) – Greenish- or medium-bluish-gray to light-bluish-gray, medium- to thick-bedded limestone, argillaceous limestone, and fossiliferous limestone; typical fossils include rugose corals, crinoid columns and stems, and brachiopods; forms blocky slopes and ledges; exposed extensively across the crest and limbs of the Ophir anticline in the southwestern Oquirrh Mountains; contact with the underlying Humbug Formation is gradational and conformable and marked by transition to the calcareous sandstone typical of the Humbug Formation; upper contact with the Long Trail Shale Member is sharp and conformable, and mapped at the first laterally continuous carbonaceous shale bed; age is from Gordon and others (2000); thickness is between 460 and 560 feet (140–170 m); Gilluly (1932) reported a thickness of 500 feet (150 m).

Mh **Humbug Formation** (Upper Mississippian) – Dark-yellowish-orange to grayish-brown, interbedded quartz sandstone and medium-bluish-gray limestone; forms rubble-strewn slopes and ledges; exposed along the southwest limb of the Ophir anticline; limestone is thin to medium bedded and locally fossiliferous; sandstone is medium to thin bedded, cement is variably calcareous or siliceous; sandstone and limestone have well-developed planar and low-angle cross-stratification; common fossils in carbonate parts of the unit include broken and abraded rugose and bryozoan coral, crinoid fragments, and brachiopods; upper contact with the lower member of the Great Blue Limestone is conformable and gradational and is placed above the uppermost laterally continuous sandstone bed that is approximately 3 feet (~1 m) thick; lower contact is also conformable and gradational and mapped at the base of the first laterally continuous cross-bedded sandstone bed above the Deseret Limestone; age is from Morris and Lovering (1961); thickness in the Ophir quadrangle is between 640 and 760 feet (195–230 m); Gilluly (1932) reported a thickness of 650 feet (198 m) for the southwest Oquirrh Mountains; regional thickness is between 350 and 1550 feet (110–470 m) (Hintze and Kowallis, 2009).

Md **Deseret Limestone** (Upper to Lower Mississippian) – Medium-dark-gray to grayish-black limestone with grayish-black to dusky-brown phosphatic shale near the base; forms prominent cliffs and ledges; outcrops along the slopes of Ophir Canyon; consists of an upper section of medium- to thick-bedded micritic limestone and a thin lower section of phosphatic shale, thin-bedded limestone, and sandy limestone; limestone is generally medium or thick bedded, micritic, and occasionally displays trough cross-bedding; dark-colored chert blebs and stringers are also common; lower contact is sharp and conformable and mapped at the base of slope-forming phosphatic shale (Delle Phosphatic Member); upper contact is gradational and conformable and placed at the base of first laterally continuous Humbug quartzose sandstone bed 3 feet (~1 m) thick; age is from Sandberg and others (1982); thickness in Ophir quadrangle is between 520 and 820 feet (160–250 m); Gilluly (1932) reported a measured thickness of 650 feet (200 m) on the north wall of Ophir Canyon; regional thickness is between 500 and 1175 feet (150–360 m) (Hintze and Kowallis, 2009).

Mg **Gardison Limestone** (Lower Mississippian) – Grayish-blue to dusky blue, medium- to thin-bedded limestone and cherty limestone; consists of an upper section of medium- or thick-bedded, cliff-forming, cherty limestone underlain by slope-forming, thin-bedded, argillaceous or micritic limestone; the sharp lower contact may be a regional unconformity and is placed above the resistant cliff-forming limestone of map unit MDfp; exposed along Ophir Canyon and across the southwest flank of Dry Mountain; upper contact is sharp and placed above the cliff-forming chert-banded limestone typical of the upper Gardison Limestone; age is from Sandberg and others (1982); thickness in the Ophir quadrangle is between 460 and 530 feet (140–160 m); Gilluly (1932) measured a thickness of 460 feet (140 m) on the north wall of Ophir Canyon; regional thickness is between 300 and 1100 feet (90–340 m) (Hintze and Kowallis, 2009).

MISSISSIPPIAN-DEVONIAN

MDgp **Gardison Limestone, Fitchville Formation, and Pinyon Peak Limestone, undivided** (Lower Mississippian and Upper Devonian) – Combined unit that includes the Gardison Limestone, Fitchville Formation, and Pinyon Peak Limestone; shown only on cross section; thickness is between 580 and 670 feet (180–200 m).

MDfp **Fitchville Formation and Pinyon Peak Limestone, undivided** (Lower Mississippian and Upper Devonian) – Grayish-blue to medium-dark-gray dolomite, argillaceous dolomite, limestone, and sandy limestone; unit forms prominent cliff and short slope immediately above the Lynch Dolomite; exposed in Ophir Canyon and to the north on Dry Mountain; within the upper part of the cliffy dolomite several beds contain conspicuous white calcite blebs up to 4 inches (10 cm) in diameter; lower contact is sharp and disconformable and marks a major period of pre-Late Devonian erosion and non-deposition; this surface is marked by up to 6 feet (2 m) of erosional relief developed in the top of the Lynch Dolomite; upper contact is sharp, may be a regional unconformity, and is placed on top of the cliff-forming dark dolomite of the MDfp unit; age is from Sandberg and others (1982); thickness is between 120 and 140 feet (37–43 m); Gilluly (1932) estimated a thickness of 185 feet (56 m) on the north side of Ophir Canyon; thickness is 200 feet (60 m) in the southern Stansbury Mountains (Clark and others, 2012) and 60 feet (20 m) in the Vernon Hills (Kirby, 2010b, 2010c).

CAMBRIAN

Ꞓu **Cambrian undivided** (Upper to Lower Cambrian) – Combined unit that includes the Lynch Dolomite, Bowman Limestone, Hartmann Limestone, Ophir Formation, and Tintic Quartzite; may also include older units not exposed in the Ophir quadrangle; shown only on cross section; thickness is greater than 5000 feet (1520 m).

Ꞓly **Lynch Dolomite** (Upper to Middle Cambrian) – Grayish-blue, argillaceous dolomite and dolomite; unit comprises medium- to thick-bedded, fine-grained dolomite and interbedded silty dolomite with thin, light-colored, shaly partings; forms cliffs and slopes; exposed in Ophir Canyon and on Dry Mountain; contact with the underlying Bowman Limestone is conformable and gradational and placed at the transition from limestone (Ꞓb) to argillaceous dolomite (Ꞓly); upper contact with the overlying MDfp unit is sharp and disconformable; thickness north of Ophir Canyon is between 810 and 1050 feet (250–320 m); age is poorly constrained and based on a single *Hyolithes* collection (Gilluly, 1932) and regional correlation (Gilluly, 1932; Tooker; 1987; Clark and others, 2012); previous workers reported thicknesses between 820 and 1000 feet (250–305 m) (Gilluly, 1932; Tooker, 1987).

Ꞓb **Bowman Limestone** (Middle Cambrian) – Grayish-yellow to light-greenish-gray limestone and argillaceous limestone; forms ledgey slopes and small cliffs; exposed near the core of the Ophir anticline in Ophir Canyon; contains up to 40 feet (12 m) of olive-gray to moderate-yellowish-brown hornfels at its base; lower contact is conformable and sharp and placed at the base of the laterally continuous hornfels bed; above this, the unit consists of limestone beds with prominent sections of intraformational conglomerate and oolitic limestone; age is poorly constrained, Tooker (1987) reported a sparse trilobite fauna; thickness is between 310 and 345 feet (95–105 m); previous workers reported a thickness of ~ 280 feet (85 m) (Gilluly, 1932; Tooker, 1987).

Ꞓh **Hartmann Limestone** (Middle Cambrian) – Grayish-blue to dusky-blue, thin- to medium-bedded and mottled argillaceous limestone; forms slopes and small ledges; exposed near the core of the Ophir anticline in Ophir Canyon; individual limestone beds range from 1 inch (2.5 cm) to several feet thick and are separated by thin shaley partings; upper part contains oolitic limestone and *Girvanella* beds; lower contact is sharp and conformable and marked by the first argillite or shale bed of the underlying Ophir Formation; upper contact is also sharp and conformable and placed at the base of a prominent hornfels bed; age is poorly constrained and based on relative stratigraphic position above the Ophir Formation and Tintic Quartzite; Gilluly (1932) reported a trilobite fauna; total thickness is between 590 and 630 feet (180–190 m); Gilluly (1932) measured a thickness of 650 feet (200 m).

Ꞓop **Ophir Formation** (Middle Cambrian) – Dusky-yellow-green to dusky-red shale, micaceous shale, argillite, and siltstone; unit includes several medial limestone beds up to 3 feet (1 m) thick; forms slopes and ledges; exposed in the core of the Ophir anticline in Ophir Canyon; upper and lower contacts are gradational and conformable; upper contact is mapped above uppermost laterally continuous shale bed; base of the unit is mapped at the base of the lowest significant shale bed; age is from Morris and Lovering (1961); total thickness in the core of the Ophir anticline is between 280 and 310 feet (85–95 m); Gilluly (1932) gave a thickness of 320 feet (98 m); thickness to the south in the northern East Tintic Mountains is 430 feet (130 m) (Morris and Lovering, 1961; Clark and others, 2012).

Ꞓt **Tintic Quartzite** (Middle to Lower Cambrian) – Dark-yellowish-orange to dark-yellowish-brown, medium- to thick-bedded orthoquartzite; forms prominent cliffs along the north slope of Ophir Canyon near the core of the Ophir anticline; commonly displays well-developed trough cross-beds; upper contact is conformable and gradational and placed above last quartzite bed thicker than 2 feet (0.7 m); shale and argillite interbeds occur near the upper contact with the Ophir Formation; base of unit is not exposed; age is from Morris and Lovering (1961); exposed thickness up to 310 feet (95 m); thickness to the south in the northern East Tintic Mountains is approximately 2500 feet (760 m) (Morris and Lovering, 1961; Clark and others, 2012).

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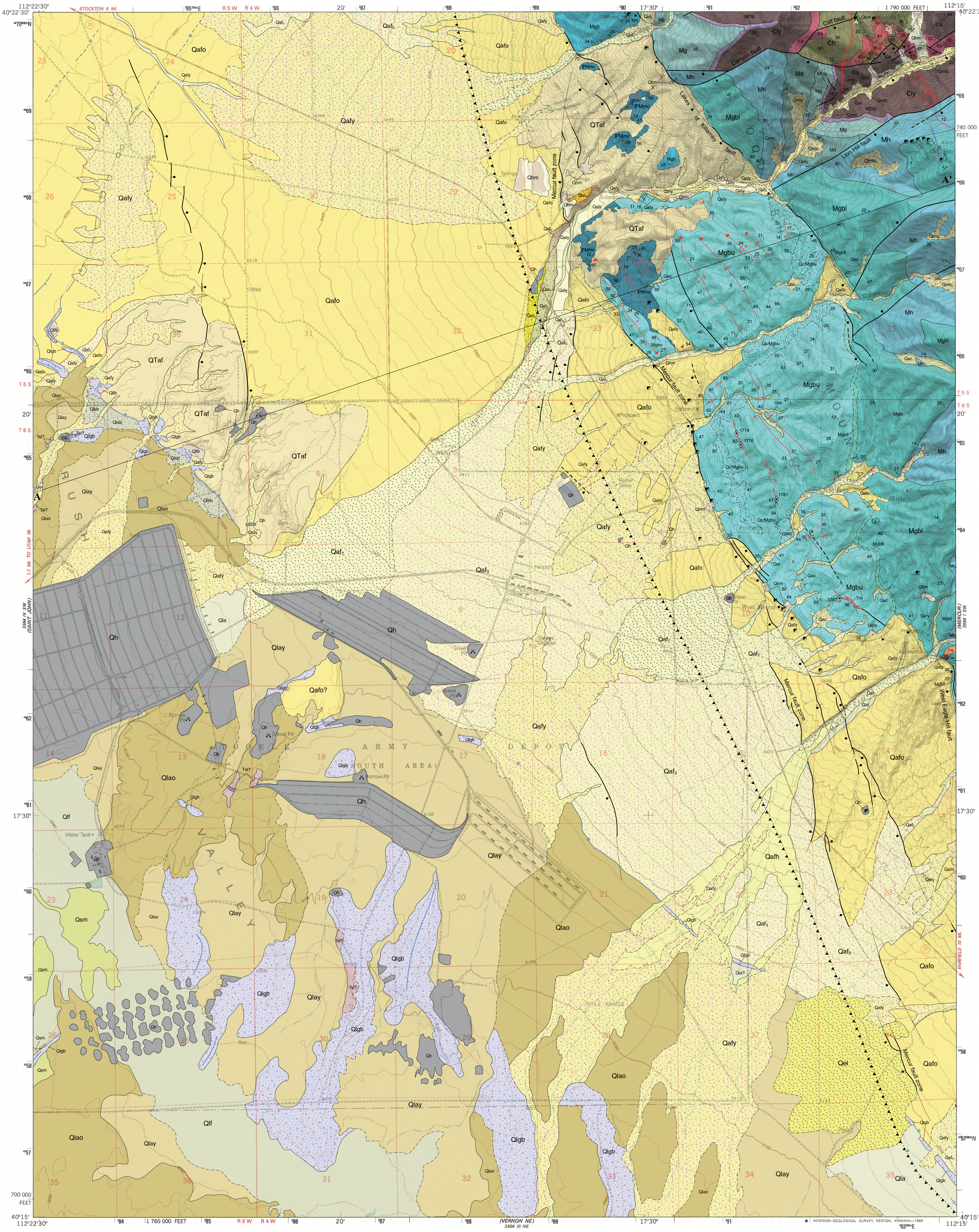

This geologic map was funded by the Utah Geological Survey and the U.S. Geological Survey, National Cooperative Geologic Mapping Program, through USGS STATEMAP award number G10AC00386.

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SCALE 1:24,000

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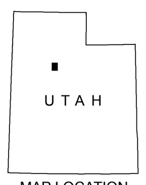
CONTOUR INTERVAL 40 FEET
SUPPLEMENTARY CONTOUR INTERVAL 20 FEET



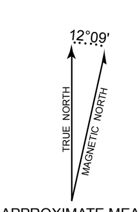
MAP LOCATION

GEOLOGIC MAP OF THE OPHIR QUADRANGLE, TOOELE COUNTY, UTAH

by

Stefan M. Kirby

2012



APPROXIMATE MEAN DECLINATION, 2012

1	2	3
4		5
6	7	8

1. South Mountain
2. Stockton
3. Lowe Peak
4. Saint John
5. Mercur
6. Faust
7. Vernon NE
8. Five Mile Pass

ADJOINING 7.5' QUADRANGLE NAMES

Base from USGS Ophir 7.5' Quadrangle (1993)
Projection: UTM Zone 12
Datum: NAD 1927
Spheroid: Clarke 1866

Project Manager: Donald L. Clark
GIS and Cartography: Jay C. Hill, Richard L. Emerson

Utah Geological Survey
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P.O. Box 146100, Salt Lake City, UT 84114-6100
(801) 537-3300
geology.utah.gov

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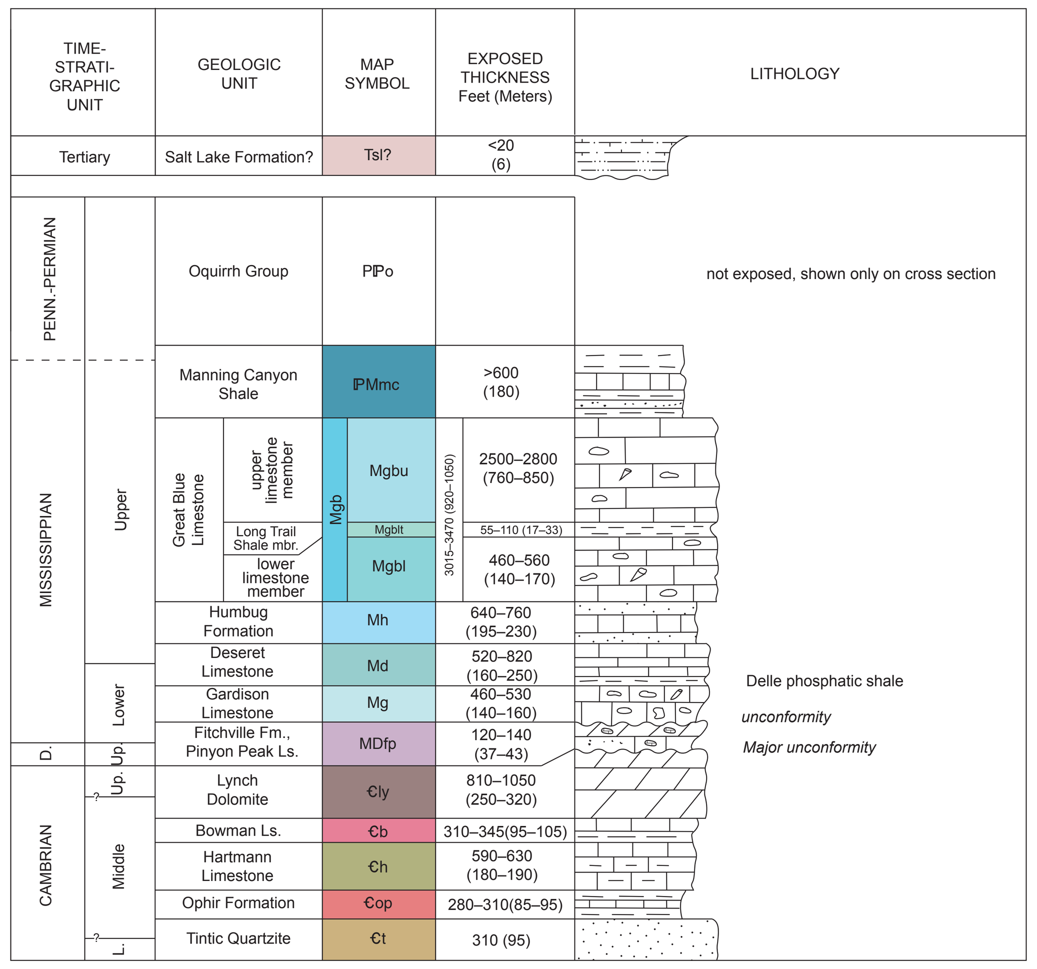
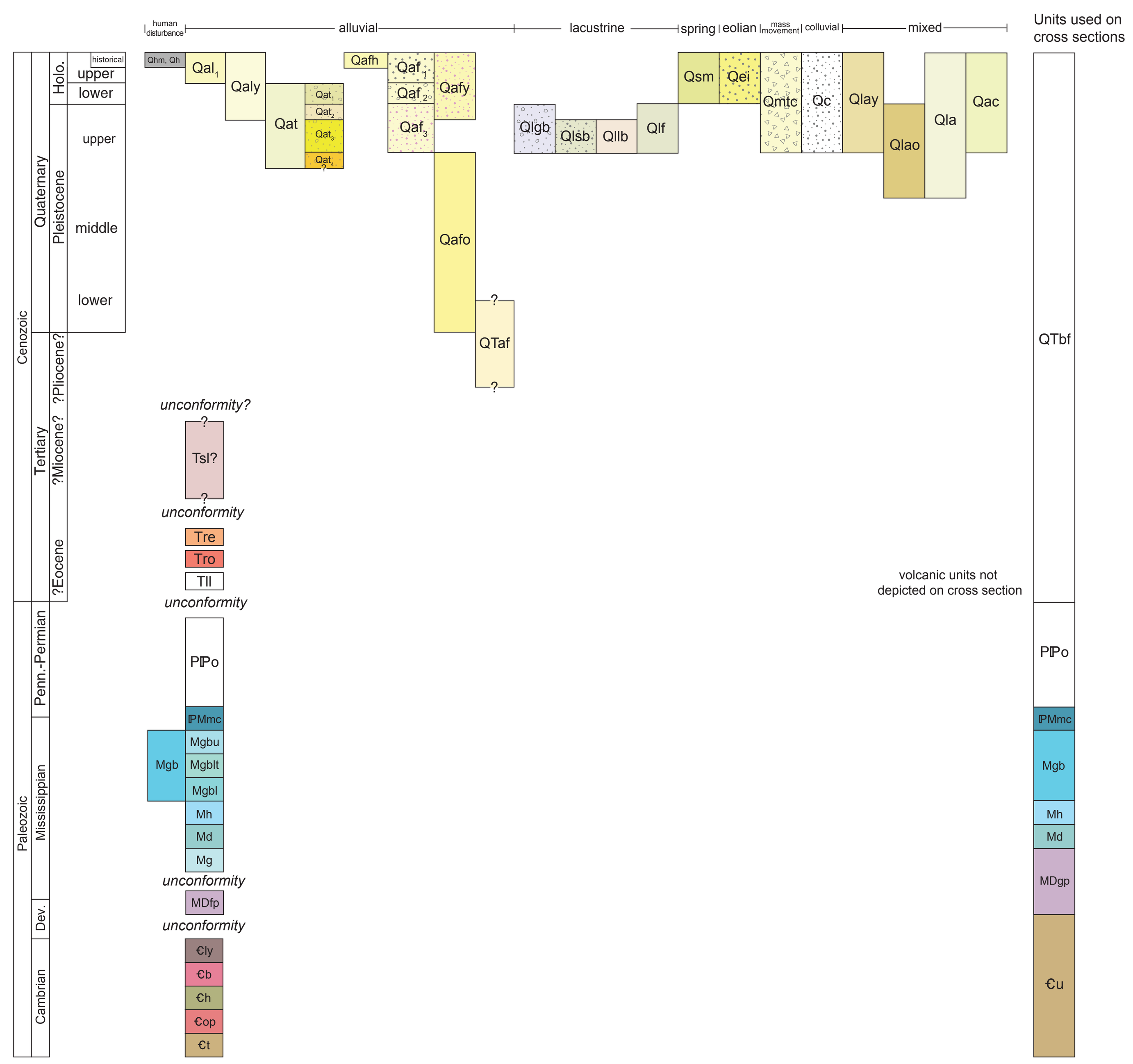
LITHOLOGIC COLUMN



CORRELATION OF GEOLOGIC UNITS



View to the southwest across the Ophir quadrangle. The cliff in the foreground is southwest-dipping Fitchville Formation and Pinyon Peak Limestone with prominent white calcite blebs of the "eye bed."

View to the south across Ophir Canyon from Hartmann Gulch. The town of Ophir lies in front of cliffy exposures of the Cambrian Lynch Dolomite broadly folded along the Ophir anticline.

GEOLOGIC SYMBOLS

Contact – Dashed where approximately located

Fault of uncertain geometry – Dashed where approximately located; relative motion unknown

Normal fault – Dashed where approximately located, dotted where concealed; bar and ball on down-thrown block

Thrust fault – Dotted and queried where concealed and location is inferred

Anticline axis – Dotted where concealed; arrow indicates direction of plunge

Syncline axis – Dashed where approximately located, dotted where concealed; arrow indicates direction of plunge

Highest shoreline of the Bonneville transgressive phase; dashed where approximately located, dotted where concealed

Other transgressive shorelines of the Bonneville phase; dashed where approximately located

Lacustrine beach ridge or gravel bar crest

Silicic dike (map unit Tre)

Mafic dike (map unit Tll)

Strike and dip of inclined bedding –

23 Strike and dip measured during this study

15 Strike and dip compiled from Tooker (1987) or Gilluly (1932)

Volcanic rock geochemical and zircon sampling site – Number corresponds with tables 2 through 4

Quarry

Prospect

Sand and gravel pit

Adit

Shaft

Well

Paleoseismic trench location

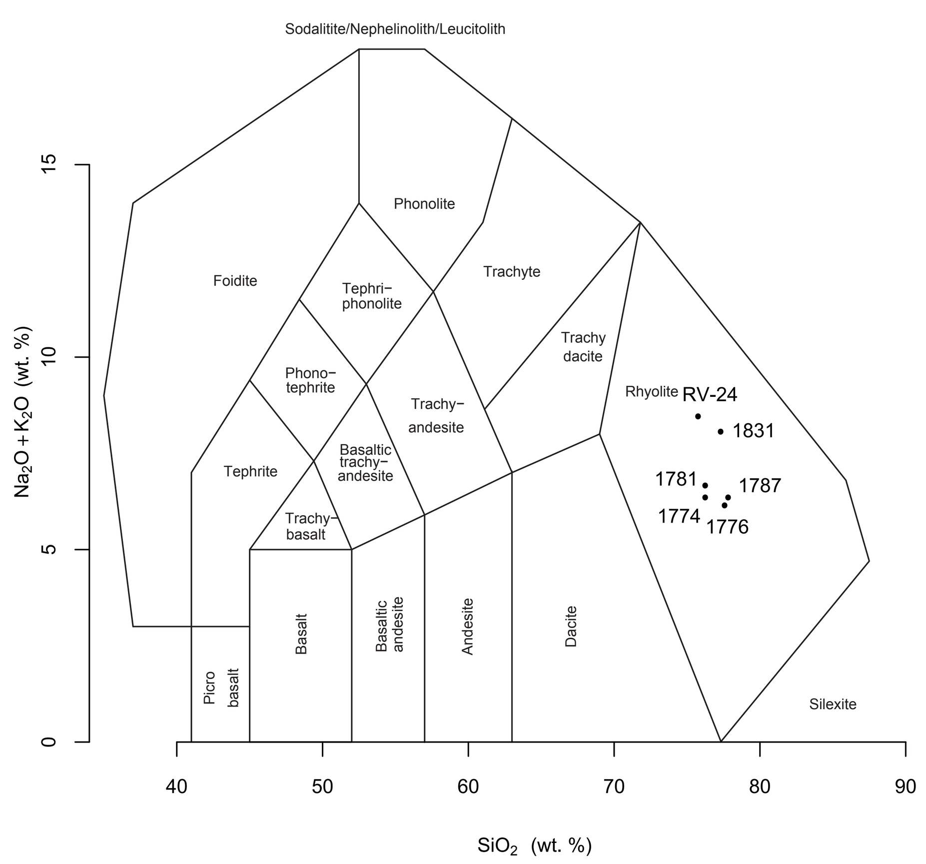


***Figure 1.** Total alkali-silica diagram and plot of volcanic rock samples, using the scheme of Middlemost (1994), from the Ophir quadrangle. Sample location and geochemical data presented in table 2.*

***Table 4.** U-Pb zircon data for analyses of Ophir Canyon rhyolite dike (site ID 1831).*

	Isotopic Ratios						Ages (Ma)					
Analysis ID	$^{207}Pb/^{235}U$	±2σ	$^{206}Pb/^{238}U$	±2σ	$^{207}Pb/^{206}Pb$	±2σ	$^{207}Pb/^{235}U$	±2σ	$^{206}Pb/^{238}U$	±2σ	$^{207}Pb/^{206}Pb$	±2σ
115801_4_Zrn	0.03673	0.00109	0.00562	0.00025	0.04742	0.00176	36.63	1.11	36.14	1.61	70.24	87.20
115801_5_Zrn	0.03683	0.00112	0.00563	0.00025	0.04747	0.00179	36.73	1.14	36.17	1.63	72.80	88.57
115801_7_Zrn	0.03954	0.00127	0.00596	0.00028	0.04816	0.00189	39.38	1.29	38.33	1.77	107.11	91.47
115801_8_Zrn	0.03664	0.00108	0.00560	0.00025	0.04745	0.00175	36.54	1.10	35.97	1.60	71.72	86.68
115801_9_Zrn	0.03744	0.00110	0.00572	0.00025	0.04742	0.00175	37.32	1.12	36.78	1.63	70.37	86.65
115801_26_Zrn	0.03932	0.00125	0.00596	0.00028	0.04781	0.00187	39.16	1.27	38.32	1.78	89.92	91.38
115801_27_Zrn	0.03854	0.00123	0.00578	0.00026	0.04828	0.00188	38.40	1.25	37.16	1.69	113.18	90.66
115801_28_Zrn	0.03666	0.00110	0.00556	0.00025	0.04777	0.00179	36.56	1.12	35.75	1.60	88.12	87.41
115801_32_Zrn	0.03714	0.00112	0.00566	0.00025	0.04761	0.00178	37.03	1.14	36.37	1.63	80.10	87.75
115801_34_Zrn	0.03648	0.00108	0.00558	0.00025	0.04749	0.00176	36.39	1.10	35.85	1.59	74.07	86.70
115801_35_Zrn	0.03783	0.00112	0.00575	0.00026	0.04777	0.00177	37.70	1.14	36.94	1.64	87.90	86.61
115801_39_Zrn	0.03735	0.00112	0.00566	0.00025	0.04785	0.00178	37.23	1.13	36.37	1.63	92.07	87.13
115801_42_Zrn	0.03741	0.00112	0.00571	0.00025	0.04757	0.00177	37.29	1.14	36.68	1.64	78.01	87.44
115801_43_Zrn	0.03751	0.00116	0.00564	0.00026	0.04819	0.00185	37.39	1.18	36.25	1.65	108.44	89.40
115801_50_Zrn	0.03586	0.00128	0.00537	0.00025	0.04839	0.00206	35.77	1.30	34.55	1.64	118.47	98.96

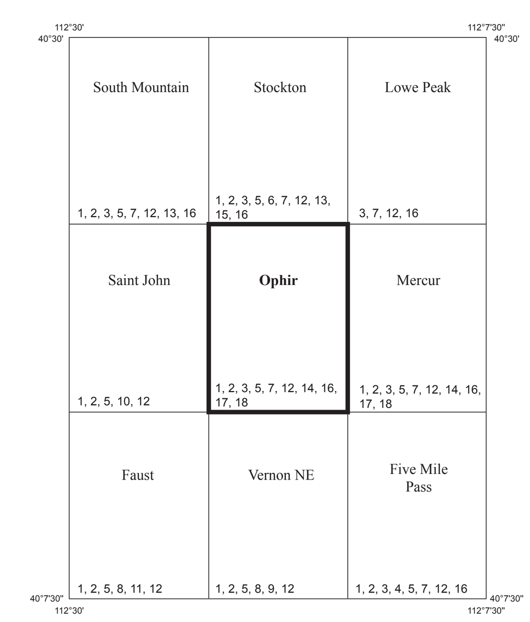
Zircon age summary: weighted mean age 36.4 Ma, uncertainty 1.4 Ma, MSWD 1.18 Ma

Analyses completed at Apatite to Zircon, Inc., Viola, Idaho

***Table 1.** Ages and elevations of major shorelines of Lake Bonneville in the Ophir quadrangle.*

Lake Cycle and Phase	Shoreline (map symbol)	Age: radiocarbon years B.P.	Age: calendar-calibrated years B.P.	Elevation feet (meters)
Lake Bonneville				
Transgressive Phase	Bonneville (B)	15,000–14,500[1]	18,300[2]–17,400[3]	5220–5190 (1591–1587)
	flood			
Regressive Phase	Not mapped in the Ophir quadrangle			

[1] Oviatt and others (1992), Oviatt (1997).
[2] Oviatt (written communication, 2009), using Stuiver and Reimer (1993) for calibration.
[3] CRONUS-Earth Project (2005), using Stuiver and others (2005) for calibration.



Index to U.S. Geological Survey 7.5-minute quadrangles, and sources of geologic information (refer to numbered list).

***Table 2.** Summary of whole-rock geochemical data for volcanic rocks in the Ophir quadrangle.*

Site ID	East[1]	North[1]	7.5' Quadrangle	Map Unit	TAS classification[2]	SiO_2 (%)[3]	Al_2O_3 (%)	Fe_2O_3 (%)	CaO (%)	MgO (%)	Na_2O (%)	K_2O (%)	Cr_2O_3 (%)	TiO_2 (%)	MnO (%)	P_2O_5 (%)	SrO (%)	BaO (%)	LOI (%)[4]	Total (%)
1774	391304	4465081	Ophir	Tro	Rhyolite	72.02	13.6	0.74	1.22	0.67	1.3	4.7	<0.01	0.1	0.03	0.031	0.01	0.06	5.13	99.6
1776	391354	4464951	Ophir	Tro	Rhyolite	73.38	13.63	0.69	0.84	0.57	1.38	4.52	<0.01	0.1	0.03	0.032	0.02	0.05	4.86	100.1
1781	391729	4464305	Ophir	Tro	Rhyolite	71.11	13.19	0.8	1.26	0.66	1.49	4.57	<0.01	0.1	0.03	0.03	0.02	0.05	5.2	98.51
1787	392515	4463187	Ophir	Tro	Rhyolite	74.25	13.77	0.46	0.51	0.41	1.75	4.3	<0.01	0.06	0.04	0.018	0.01	<0.01	4.14	99.72
1831	392571	4468988	Ophir	Tro	Rhyolite	76.05	13.3	0.56	0.1	0.41	0.24	7.79	<0.01	0.05	0.05	0.016	0.01	0.07	1.31	99.96
RV-24	396473	4462674	Mercur	Tri[5]	Rhyolite	73.1	13.06	0.66	0.87	0.47	0.82	7.38	<0.01	0.1	0.03	0.025	0.02	0.09	2.75	99.38

[1]Coordinates in UTM NAD 27 zone 12N
[2]Rock type classification based on TAS scheme (Middlemost, 1994)
[3]Major element whole-rock geochemistry in weight percent determined by XRF analyses
[4]LOI is loss on ignition
[5]Eagle Hill Rhyolite; see Clark and others (2012)
Analyses by ALS Minerals, Reno, Nevada

SOURCES OF GEOLOGIC INFORMATION

1 Barnhard, T.P., and Dodge, R.L., 1988, Map of fault scarps formed in unconsolidated sediments, Tooele 1º x 2º quadrangle, northwestern Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-1990, scale 1:250,000.

2 Bucknam, R.C., 1977, Map of suspected fault scarps in unconsolidated deposits, Tooele 2° sheet, Utah: U.S. Geological Survey Open-File Report 77-495, scale 1:250,000.

3 Clark, D.L., Kirby, S.M., and Oviatt, C.G., 2012, Interim geologic map of the Rush Valley 30' x 60' quadrangle, Tooele, Utah, and Salt Lake Counties, Utah: Utah Geological Survey Open-File Report 593, 65 p., 1 plate, scale 1:62,500.

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14 Tooker, E.W., 1987, Preliminary geologic maps, cross sections, and explanation pamphlet for the Ophir and Mercur 7.5-minute quadrangles, Utah: U.S. Geological Survey Open-File Report 87-152, 18 p., 3 plates, scale 1:24,000.

15 Tooker, E.W., and Roberts, R.J., 1992, Preliminary geologic map of the Stockton 7.5-minute quadrangle, Tooele County, Utah: U.S. Geological Survey Open-File Report 92-385, 2 plates, scale 1:24,000.

16 Tooker, E.W., and Roberts, R.J., 1998, Geologic map of the Oquirrh Mountains and adjoining south and western Traverse Mountains, Tooele, Salt Lake and Utah Counties, Utah: U.S. Geological Survey Open-File Report 98-581, 2 plates, scale 1:50,000.

17 URS Greiner Woodward Clyde, 1999, Mapping and Quaternary fault scarp analysis of the Mercur and West Eagle Hill faults, Wasatch Front, Utah: Oakland, California, unpublished consultant's report for the U.S. Geological Survey under award number 1434-HQ-97-GR-03154, variously paginated, 3 appendices.

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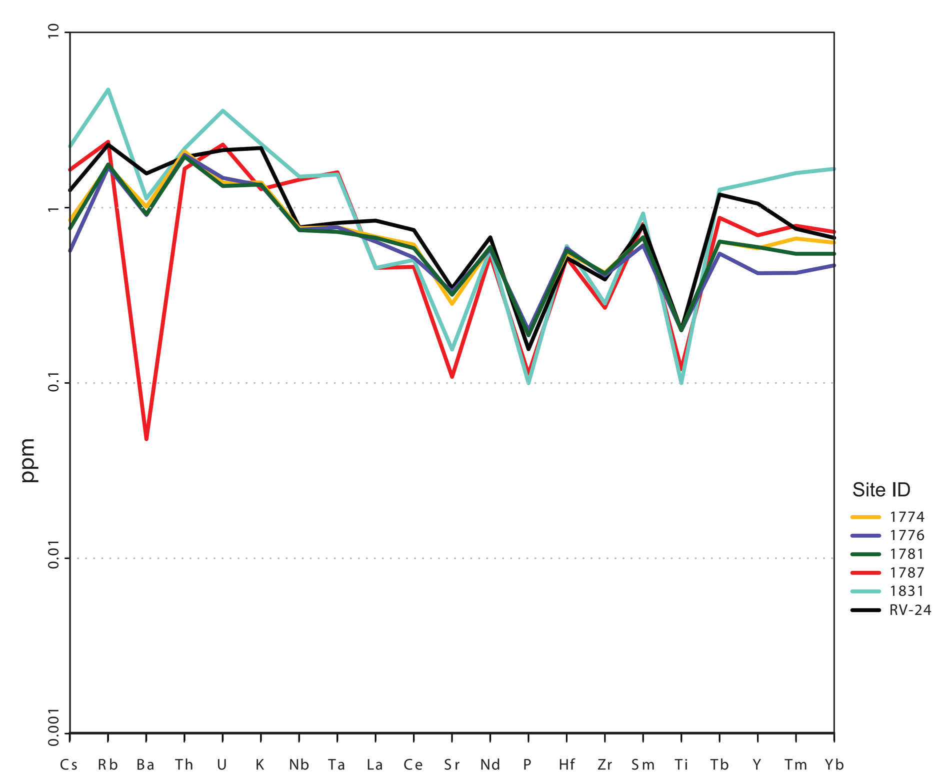

***Figure 2.** Spider diagram of normalized trace-element composition of volcanic rocks in the Ophir quadrangle. Data are normalized for upper continental crust using the methodology of Taylor and McLennan (1995). Trace-element geochemical data are presented in table 3.*

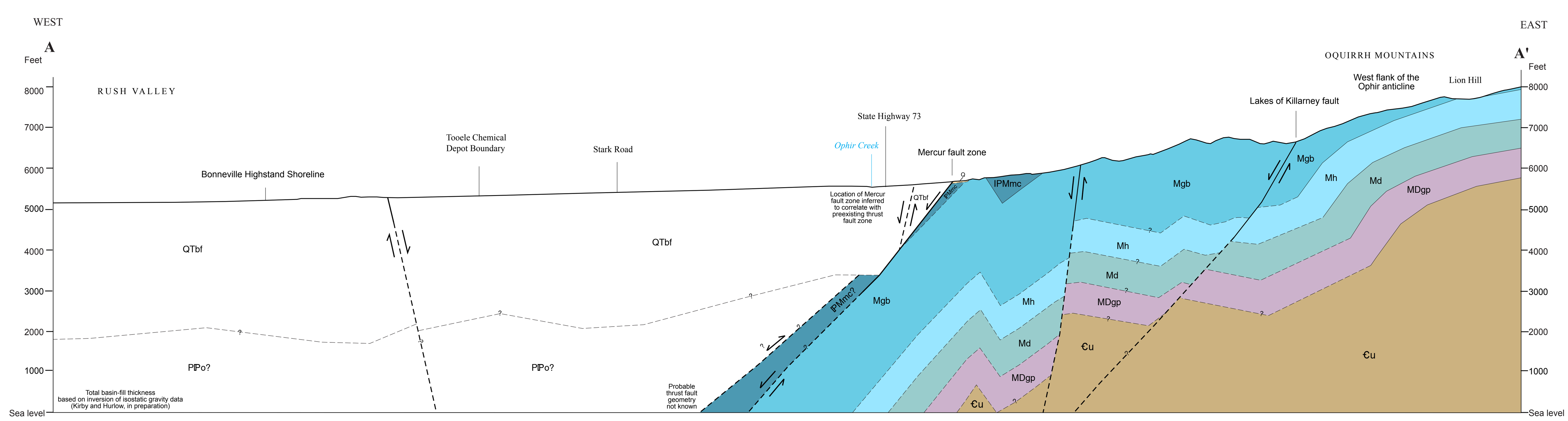

***Table 3.** Trace-element geochemistry for volcanic rocks in the Ophir quadrangle.*

Site ID	Ag (ppm)	Ba (ppm)	Ce (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Cu (ppm)	Dy (ppm)	Er (ppm)	Eu (ppm)	Ga (ppm)	Gd (ppm)	Hf (ppm)	Ho (ppm)	La (ppm)	Lu (ppm)	Mo (ppm)
1774	<1	557	39.4	0.6	<10	3.14	<5	2.29	1.33	0.59	18.9	2.6	3.2	0.44	20.5	0.21	<2
1776	<1	500	33.2	<0.5	<10	2.1	<5	1.85	1	0.58	18.8	2.3	3.4	0.31	19.2	0.14	2
1781	<1	505	37.6	0.5	<10	2.82	<5	2.16	1.22	0.59	18.6	2.63	3.3	0.41	20.2	0.17	<2
1787	<1	26.3	29.4	<0.5	<10	6.09	<5	3.2	1.6	0.25	21.8	3.21	3	0.55	13.6	0.24	<2
1831	<1	621	32.2	<0.5	<10	8.28	<5	5.35	3.25	0.27	17.9	3.97	3.5	1.06	13.6	0.54	<2
RV-24	<1	862	47.7	0.6	<10	4.65	<5	4.15	1.78	0.66	17.5	4.11	3	0.72	25.3	0.21	<2

Site ID	Nb (ppm)	Nd (ppm)	Ni (ppm)	Pb (ppm)	Pr (ppm)	Rb (ppm)	Sm (ppm)	Sn (ppm)	Sr (ppm)	Ta (ppm)	Tb (ppm)	Th (ppm)	Tl (ppm)	Tm (ppm)	U (ppm)	V (ppm)	W (ppm)	Y (ppm)	Yb (ppm)	Zn (ppm)	Zr (ppm)
1774	19.1	15.4	<5	30	4.15	192.5	3.04	1	98.9	1.7	0.41	22.4	2.1	0.22	3.89	9	2	12.9	1.39	33	81
1776	18.7	15.1	5	29	4.1	190.5	2.74	2	116	1.7	0.35	21.4	2.7	0.14	4.14	7	2	9.3	1.03	42	78
1781	18.6	15.5	<5	31	4.16	197.5	3.05	1	111.5	1.6	0.41	20.9	2.1	0.18	3.72	5	2	13.1	1.2	38	80
1787	36.1	13.9	6	34	3.61	266	3.63	3	37.9	3.5	0.56	17.85	3.5	0.26	6.41	<5	2	15.3	1.6	58	51
1831	37.6	15.1	<5	43	3.76	528	4.17	2	54.3	3.4	0.81	23.3	5.8	0.52	10	<5	3	31	3.66	77	54
RV-24	19.3	17.6	<5	24	5.3	256	3.55	2	121.5	1.8	0.76	20.8	0.7	0.25	5.96	9	2	23.2	1.48	17	74

Trace-element geochemistry determined by ICP-MS
Analyses by ALS Minerals, Reno, Nevada